Description

Device and method for measuring individual cell voltages in a cell stack of an energy accumulator.

The invention relates to a device for measuring individual cell voltages in a cell stack of an energy accumulator, especially of an energy accumulator in a motor vehicle electrical system.

The invention also relates to a method for operating this device.

In motor vehicle electrical networks, as well as today's usual lead acid accumulators, other energy accumulators also constructed from individual cells will be used, for example nickel-metal-hydride accumulators, Lithium-Ion accumulators and double-layer capacitors.

In lead-acid accumulators the charge provided of the individual cells of the accumulator is balanced out by a slight overcharging of the accumulator as a whole until such time as all cells are finally charged.

Balancing the charge between a weakly-charged accumulator

and the group of the remaining accumulators in a plurality of series-connected accumulators by means of a square-wave generator which is connected to these accumulators via a transformer is known from EP 0 432 639 A2.

With the new types of energy accumulator mentioned however the sensitivity of the individual cells to overcharging or overvoltage is a problem. In contrast to lead-acid accumulators, with a lithium-ion accumulator for example the charge voltage of a cell cannot significantly exceed a value of around 4.2V since otherwise the danger of destruction or even of the cell catching fire arises. With double-layer capacitors the maximum charge voltage is about 2.5 to 2.7V.

As a result of production-related differing variation of the self-discharge of the cells, the charge states and cell voltages in a cell stack will assume different values over longer periods of operation.

One problem here is that as a rule only the overall voltage of the cell stack, i.e. of the energy accumulator, can be recorded as the pole voltage, but not the voltage of each individual cell. Thus charge balancing can only be undertaken periodically "on suspicion". If however an increased self-discharge - such as towards the end of the

life of the energy accumulator - or an error in a individual cell occurs, for example a short circuit, this cannot be detected immediately. The result of this can be that during the next charge process the charge voltage is divided between fewer cells, so that individual cells are subjected to an increased voltage. This then leads to the destruction of further cells and must be avoided in any event.

It is therefore very desirable to know the voltages of the individual cells in a cell stack of such an energy accumulator in order to be able to react in the appropriate manner.

The measurement of the individual cell voltages is difficult since only the lowest cell has a ground reference point, meaning that it can be recorded with reference to ground (reference potential) whereas for all other cells a conversion to ground potential is necessary in order to be able for example to detect them via the analog/digital converter of a microcontroller.

The object of the invention is to create a device to measure the voltages of the individual cells of a cell stack in an energy accumulator. Another object of the invention is to specify a method for operating this device.

According to the invention this object is achieved by a device in accordance with the features of claim 1 and a method in accordance with the features of claim 3.

Embodiments according to the invention are explained below in more detail with reference to a schematic drawing.

Advantageous developments of the invention can be taken from the subclaims.

The drawing shows the following:

Figure 1 a basic circuit diagram of a device for measurement of the cell voltages of a cell stack consisting of a number of cells,

Figure 2 a detailed circuit diagram of a first device for measurement of the voltage of an individual cell,

Figure 3 input and output signals of the differential amplifier Diff1 used in the first circuit,

Figure 4 input and output signals of the synchronous rectifier Amp1 used in the first circuit,

Figure 5 a detailed circuit diagram of a second device with an alternative synchronous rectifier Diff2,

Figure 6 input and output signals of the differential amplifier Diff1 used in the second circuit,

Figure 7 input and output signals of the synchronous rectifier Diff2 used in the second circuit 2.

Figure 1 shows a basic circuit diagram of an inventive device to measure individual cell voltages in a cell stack of an energy accumulator. The Figure shows a cell stack ZS with series-connected cells Z1, Z2 to Zn of a lithium-ion accumulator for example, with the cell connections (plus and minus pole) being brought out. Further details are discussed more closely below.

The invention will be explained initially with reference to a device for voltage measurement at an individual cell in accordance with a detailed circuit diagram shown in Figure 2.

Figure 2 shows a device to measure the voltage of an individual cell Z1 of the cell stack ZS shown in Figure 1, for example of a lithium-ion accumulator with a cell voltage

Uz=4.2V, of which the minus pole is connected to reference potential GND.

Arranged in parallel to this cell Z1 is a series circuit of two diodes D1a and D1b which conduct current in the direction from the minus pole to the plus pole of the cell Z1.

The connection point of the two diodes D1a and D1b is linked via a capacitor C1 to the non-inverting input of a differential amplifier Diff1.

A reference circuit REF features two series-connected diodes D3 and D4, with the anode of the one diode - D4 - being connected to reference potential GND and to the cathode of the other diode - D3.

The connection point of the two diodes D3 and D4 is connected via a capacitor C3 to the inverting input b of the differential amplifier Diff1, of which the output c leads to the input of a rectifier, which in this exemplary embodiment is embodied as a synchronous demodulator (Amp1, R1 to R3 and S1) of which more details will be provided below.

The method in accordance with the invention for operating

this device works as follows:

Two alternating current sources I1 and I2 are controlled by an oscillator clock T1 of an oscillator not shown in Figure 2, of which the first alternating current source I1, arranged between the non-inverting input of the differential amplifier Diff1 or the capacitor C1 and reference potential GND, injects an alternating current into the capacitor C1, while the second alternating current source 12, arranged between the inverting input of the differential amplifier Diff1 or the capacitor C3 and reference potential GND injects an alternating current into the capacitor C3 of the reference circuit REF.

Alternating current source I1 applies a square-wave alternating current of for example ±100µA to the capacitor C1 The clock frequency in this case is to be selected so that it is high enough for the capacitor not to be significantly charged or discharged during the period of oscillation.

The input and output signals of the differential amplifier Diff1 and of the operational amplifier Amp1 are shown in Figures 3 and 4 to which reference will be made during the course of the description.

The signals in Figures 3, 4, 6 and 7 are shown in the steady state in each case.

With a positive current the voltage at the two terminals of the capacitor C1 will increase until such time as the diode D1a becomes conductive; with negative current the voltage at the two terminals of the capacitor will decrease until such time as the diode D1b becomes conductive.

This thus produces a square-wave alternating voltage for which the peak-to-peak value in the steady state corresponds to the cell voltage Uz, multiplied by the on-state voltages Ud of the two diodes D1a and D1b: V1 = Uz + 2Ud = 4.2V + 2*0.64V = 5.48V = ±2.74V (see Figure 3a).

The alternating current source I2 drives the capacitor C3 with the same capacitance (C3 = C1) and current value ±100µA via the on-state voltages of the two diodes D3 and D4. Since these two diodes are connected to reference potential GND, the alternating voltage here amounts to V2 = 0V + 2*0.64V = 1.28V = ±0.64V (see Figure 3b). This is the alternating voltage reference.

The difference V1 - V2 is now formed in the differential amplifier Diff1: V1 - V2 = 5.48V - 1.28V = 4.2V. Since the

differential amplifier in this exemplary embodiment for example has an amplification factor of "2", an alternating voltage of 8.4V = ±4.2V appears at its output c (see Figure 3c).

The output voltage of the differential amplifier Diff1 is now fed to the synchronous demodulator Amp1. The modulator's input signal at the inverting input corresponds to the output signal of the differential amplifier Diff1 (Figure 4a = Figure 3c).

The synchronous demodulator consists of an operational amplifier Amp1, resistors R1 to R4 and a capacitor C4. A switch S1 is arranged between the non-inverting input of the operational amplifier Amp1 and reference potential GND, which is switched over by the oscillator clock T1 (Figure 4b).

When switch S1 is open (positive amplitude of the square-wave signal) the operational amplifier Amp1 has an amplification factor of "+1", when switch S1 is closed (negative amplitude of the square-wave signal), it has a factor of "-1". Figure 4b indicates how switch S1 periodically connects the non-inverting input of the operational amplifier Amp1 to reference potential and thus

switches over the amplification factor.

The output signal V= at the output of the circuit follows the output signal of the operational amplifier Amp1, filtered by a filter formed from the resistor R4 and capacitor C4, in which case any switching problems are eliminated. The output signal V= corresponds to the voltage Uz of the cell Z1 and can be tapped at the output of the synchronous demodulator, related to reference potential GND (or ground potential, 0V).

Figure 5 shows a further detailed switching diagram as shown in Figure 2 but with an alternate version of the synchronous demodulator consisting of the components Diff2, S2, S3, C5 and C6.

The circuit from the cell Z1 via the diodes D1a, D1b, D3, D4, the capacitors C1 and C3 as well as the alternating current sources I1 and I2 up to the output of c of the differential amplifier Diff1 corresponds to the circuit shown in Figure 2. The input signals at the inputs a (Figure 6a) and b (Figure 6b) correspond to those shown in Figure 3a and 3b.

The output signal at output c of the differential amplifier

Diff1 is connected by means of two parallel switches S2 and S3 with the oscillator clock T1

- alternately to a capacitor C5 as well as the non-inverting input of a further differential amplifier Diff2, or
- to a capacitor C6 as well as to the inverting input b of the further differential amplifier Diff2

For a positive amplitude of the oscillator clock T1 switch S2 is closed (conductive) and switch 3 opened; For a negative amplitude of the oscillator clock T1 switch S3 s closed and switch 2 is opened. This means that capacitor C5 is charged at the positive value (Figure 7b) and capacitor C6 at the negative value (Figure 7b) of the alternating voltage output signal appearing at the output c of the differential amplifier Diff1(Figure 7a = Figure 6c).

The further differential amplifier Diff2 now forms the difference between the two direct currents present at its inputs a and b (in the Example: +2.10V and -2.10V = 4.20V: Figure 7c), which can be tapped at its output c as grounded direct current V=, which corresponds to the cell voltage Uz.

Whereas Figures 2 and 5 each show a detailed circuit diagram for measuring an individual cell voltage to enable the

method to be better explained, Figure 1 shows a basic circuit diagram of an inventive device to measure a plurality of cell voltages in a cell stack of an energy accumulator.

The Figure shows a cell stack ZS with series-connected cells Z1, Z2 to Zn of a lithium-ion accumulator for example. Arranged in parallel to each cell is the series circuit of two diodes D1a-D1b to Dna-Dnb which conduct current in the direction from the minus pole to the plus pole of the cell.

The connection points of the two diodes D1a-D1b to Dna-Dnb assigned to a cell in each case are routed via a capacitor C1 to Cn to the terminals of a changeover switch UM which connects them in turn, controlled by a divider signal T2 of a clock control ST, to its output.

The clock control ST consists of an oscillator OSZ which creates an oscillator clock signal T1, a square wave alternating voltage of a specific frequency, which is stepped down by means of a frequency divider DIV into a divider signal T2 in order to continue to switch the changeover switch UM after the cell voltage has been successfully detected.

The changeover switch UM must feature a number of switch positions corresponding to the number of cells of the cell stack, which (with the double layer capacitors) can reach an order of magnitude of between 20 and 30. This changeover switch can for example be embodied as a CMOS switch.

The two alternating current sources I1 and I2 known from Figure 2 are controlled by the oscillator clock T1 of the oscillator OSZ of which the first alternating current source I1 injects an alternating current via the changeover switch UM depending on its switch setting in to one of the capacitors C1 or C2 to Cn, while the second alternating current source I2 injects an alternating current into the capacitor C3 of the reference circuit REF, which as well as this capacitor C3, again features two diodes D3 and D4 of which the connection point is connected to the capacitor C3.

The output of the changeover switch UM and of the terminal of the capacitor C3 not connected to the diodes D3, D4 are connected to the inputs a and b of the differential amplifier Diff1, of which the output c is connected to a rectifier GLR controlled by the oscillator clock T1, at the output of which a direct current V= proportional to the relevant cell voltage Uz appears consecutively.

The rectifier GLR can be embodied as a synchronous demodulator Amp1 or Diff2 shown in Figure 2 or Figure 5.

The output signal V= of the rectifier GLR corresponds in the steady state to the voltage Uz of the cell selected in each case with the changeover switch UM, but now shifted in potential with reference to ground GND.

Accordingly with each advance of the changeover switch UM, the corresponding cell voltage is presented at the output of the rectifier GLR. As a result the individual cell voltages are mapped consecutively in relation to ground.

To monitor the cell voltages the voltage sequence can be compared in the simplest case to a lower and an upper value with a limit value comparator. Exceeding the maximum value indicates an overvoltage of the cell here; Dropping below a minimum value indicates a short circuit. This information can now be fed to a monitoring unit which takes appropriate measures in response to it; such as aborting the charging process, initiating a new charge balancing process or sending information to the driver telling them that a visit to the workshop is required.

Supervision using limit value comparators is however very

approximate. The cell involved cannot be identified for example. Also with a charge balancing process the point at which charging equilibrium has been achieved cannot be detected.

In a refined supervision using a microcontroller the voltage values V= can be recorded chronologically one after the other with reference to the switching clock of the changeover switch so that a further evaluation of the cell voltage can be undertaken using supervision software.

In charge balancing the slow balancing of the individual cell voltages is detectable so that the ending of the charge or discharge process can be defined.

A long-term supervision of the individual cells is also possible so that - on detection of the fall in the capacity of a cell, an increase of the self-discharge or an increase of the internal resistance of a cell - a warning message can be issued indicating that a trip to the workshop is necessary.

This increases the reliability of the system quite significantly and reduces the repair costs since only the defective cell has to be replaced and no longer the entire

cell stack.